U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB-287 744

Computer Cost Models for Potable Water Treatment Plants

(U.S.) Municipal Environmental Research Lab, Cincinnati, OH

Sep 78

United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

EPA-600/2-78-181
September 1978

Research and Development

PB 287744

EPA

Computer Cost Models for Potable Water Treatment Plants

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/2-78-181		PB287744

4. TITLE AND SUBTITLE	5. REPORT DATE
Computer Cost Models for Potable Water Treatment Plants	September 1978 (Issuing Date)
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Daniel L. Guttman and Robert M. Clark	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Municipal Environmental Research Laboratory--Cin.,OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268	1CC614 SOS-1 Task 33
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Same as above	Final
	14. SPONSORING AGENCY CODE
	EPA/600/14

15. SUPPLEMENTARY NOTES

16. ABSTRACT

A series of computer programs have been developed which calculate costs for specific unit treatment processes used in water treatment plants. The programs contained in this report are as follows: chlorination, chlorine dioxide, ozone and granular activated carbon adsorption. Tables are provided which display input and output variables,standardized values for variables, a key for variable input, and the costs associated with five different sized plants for all programs. In addition program listings and sample outputs for all programs are contained in an appendix. The costs generated by the programs are categorized as capital and O&M expenditures.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Computer Programs; Cost Effectiveness; Cost Estimates; Cost Control: Simulation; Unit Costs; Water Supply; Optimization; Water Treatment	Unit Processes; Water Treatment	13B 9B

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release to public.	Unclassified	71
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE PC-A04/MF-A01

EPA Form 2220-1 (9-73)

* U.S. GOVERNMENT PRINTING OFFICE 1978— 757-140/1466

EPA-600/2-78-181
September 1978

COMPUTER COST MODELS FOR POTABLE WATER TREATMENT PLANTS

by

Daniel L. Guttman
Robert M. Clark

Water Supply Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

DISCLAIMER

This report has been reviewed by the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and interplay among its components require a concentrated and integrated attack on the problem.

Research and development is that first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems (1) to prevent, treat, and manage wastewater, solid and hazardous waste, and pollutant discharges from municipal and community sources, (2) to preserve and treat public drinking water supplies, and (3) to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is a product of that research and is a most vital communications link between the researcher and the user community.

The need to know the monetary costs associated with water treatment is fundemental to a realistic planning approach for potable water supply. It is the monetary cost, in many cases, that plays the decisive role in the determination of the technology used to make water safe for consumption. This report provides a series of computer programs designed to estimate the costs of specific water treatment processes. These programs allow the user to vary a number of significant parameters which serve to

simulate the actual conditions of a water treatment plant. The use of these programs should provide the water systems manager with a tool which may be used to help formulate a strategy on how to best meet the water needs of his community.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

ABSTRACT

A series of computer programs have been developed which calculate costs for specific unit treatment processes used in water treatment plants. The programs contained in this report are as follows: chlorination, chlorine dioxide, chloramination, ozone and graular activated carbon adsorption. Tables are provided which display input and output variables, standardized values for variables, a key for variable input, and the costs associated with five different sized plants, for all programs. In addition, program listings and sample outputs for all programs are contained in an appendix. The costs generated by the programs are catagorized as capital and O&M expenditures.

TABLE OF CONTENTS

Page

Foreword iii

Abstract v

Tables vi

Figures viii

Acknowledgments ix

1. Introduction 1

2. Chlorination 4

3. Chlorine Dioxide 10

4. Chloramination 16

5. Ozonation 22

6. Granular Activated Carbon 29

7. Applications 37

8. Summary and Conclusions 43

9. Appendix 45

Preceding page blank

TABLES

Number		Page
1.	Input Variable List - Chlorination	5
2.	Output Variable List - Chlorination	6
3.	Standardized Vules Used for the Determination of Sample Costs - Chlorination	7
4.	Key for Variable Input - Chlorination	8
5.	Chlorine Costs Assuming Standardized Design Levels	9
6.	Input Variable List - Chlorine Dioxide	11
7.	Output Variable List - Chlorine Dioxide	12
8.	Standarized Values Used for the Determination of Sample Costs - Chlorine Dioxide	13
9.	Key for Variable Input - Chlorine Dioxide	14
10.	Chlorine Dioxide Costs Assuming Standardized Design Levels	15
11.	Input Variable List - Chloramines	17
12.	Output Variable List - Chloramines	18
13.	Standardized Values Used for the Determination of Sample Costs - Chloramines	19
14.	Key for Variable Input - Chloramine	20
15.	Chloramine Costs Assuming Standardized Design Levels	21
16.	Input Variable List - Ozone	23
17.	Output Variable List - Ozone	24
18.	Standardized Values Used in the Determination of Sample Costs - Ozone	25
19.	Key for Variable Input - Ozone	26

TABLES (Continuted)

Number		Page
20.	Ozone (Air) Costs Assuming Standardized Design Levels	27
21.	Ozone (Oxygen) Costs Assuming Standardized Design Levels	28
22.	Input Variable List - Granular Activated Carbon	31
23.	Output Variable List - Granular Activated Carbon	33
24.	Standardized Values Used for the Determination of Sample Costs - Granular Activated Carbon	34
25.	Key for Variable Input - Granular Activated Carbon	35
26.	Granular Activated Carbon Costs Assuming Standardized Design Levels	36

FIGURES

Number		Page
1.	Cost for 100 MGD Sand Replacement System Based on Reactivation Frequency	38
2.	Transportation Cost Versus On-Site Reactivation .	39
3.	Effect of 6% inflation on the Cost of 150 MGD Sand Replacement System	41
4.	The Cost of Ozone and GAC versus Reactivation Requency in Months	42
1A.	Listinge of Chlorine Cost Program	45
2A.	Sample Printout from Chlorine Cost Program . . .	46
3A.	Listing of Chlorine Dioxide Cost Program	47
4A.	Sample Printoug from Chlorine Dioxide Cost Program	48
5A.	Listing of Chloramine Cost Program	49
6A.	Sample Printout of Chloramine Cost Program . . .	50
7A.	Listing of Ozone Cost Program	51
8A.	Sample Printout of Ozone (Air) Cost Program . . .	53
9A.	Sample Printout of Ozone (Oxgyen) Cost Program .	54
10A.	Listing of Granular Activated Carbon Cost Program	55
11A.	Sample Printoug from Granular Activated Carbon Cost Program	58

ACKNOWLEDGEMENTS

The author would like to express gratitude to Robert M. Clark, Water Supply Research Division, for his assistance in preparing this report. The author would also like to acknowledge Richard G. Eilers, Wastewater Research Division, as the writer of the original versions of the computer programs, that were later modified for inclusion in this report.

INTRODUCTION

In December 1974, the 93rd Congress of the United States enacted legislation which placed new and more stringent regulations on the maximum contaminent level (MCL) for specified substances allowable in public drinking water supplies. This legislation has encouraged water utilities throughout the country to take a closer look at their own treatment processes and determine if they meet the legal and aesthetic standards set forth in the Safe Drinking Water Act. Many of these water utilities are now discovering that the drinking water they produce not only exceeds suggested MCL's, but that the cost of upgrading their inadequate treatment systems may be significant.

The variety of water treatment options open to the potable water producer are quite varied in type as well as price. These treatment techniques have proven to be dependent upon a number of intrinsic factors pertaining to the water utility itself. Among these factors are: the location of the water utility; the size of the water utility; the source of the raw water; the quality and characteristics of the pollutants in the raw water; and energy costs

This report contains a set of computer programs which have been developed to determine costs for chlorination, chlorine dioxide, chloramination, ozonation, and granular activated carbon processes for water treatment. The programs contained in the report were utilized to calculate costs which were presented in an earlier report entitled

"The Cost of Removing Chloriform and Other Trihalomethanes from Drinking Water Supplies."[3] These costs will provide the waterworks manager with a planning estimate on which he can base a detailed investigation into particular water treatment systems. The cost estimates produced by these programs are based on cost curves generated by Black and Veatch Consulting Engineers.[1] The computer programs were developed by the Systems and Economic Analysis Sections of EPA's Wastewater Research and Water Supply Research Division.

The costs generated by those programs are broken down into two categories: Capital Costs and Operation and Maintenance Costs. Capital costs include: construction for site preparation; plant construction; legal; fiscal and administrative services; interest during construction; start-up costs.[3] Operation and Maintenance costs include: chemical and raw material costs; labor costs; operation and maintenance costs such as utilities, annual replacement of expendable items, etc.[3] These costs are also adjusted to current dollars using EPA's Sewer and Sewage Treatment Plant Construction Cost Index and the Wholesale Price Index. Labor costs are derived from the U. S. Department of Labor's Labor Cost Index. This report is arranged so that each of its major sections parallel the major sections of the earlier report.[3] Each section also corresponds to a particular treatment type which can be used to control the level of trihalomethanes in drinking water supplies.

The tables presented in each section are of similar format. Input and important output variables are defined in two separate tables. Values for certain design variables are given so that a test run can be made on the program and compared to the sample printouts shown in the appendix.

A key for variable input is given in each section. (Note: all of the programs follow a similar procedure for variable input and utilize standard names for values used in more than one program.) The final table in each section shows the costs for each treatment process at five different flow rates. These costs will give the user a feel for the economies of scale realized when larger plant sizes are utilized in the programs.

CHLORINATION

Table 1 lists the input variables required for the program and Table 2 lists the output variables and their definitions. Table 3 contains a specific set of the design variable values from which costs are generated. Table 4 is a key for inputting the variables into the program. Table 5 contains the cost information which would result from the design values at various flow levels (1, 5, 10, 100, and 150 mgd), assuming 70% capacity. Figure 1A (Appendix A) contains a listing of the chlorine cost program used to calculate the costs for chlorination. Figure 2A is a sample printout from the chlorine cost program using standardized values found in Table 3.

It is the process of chlorination which interacts with organics in water and causes the formation of trihalomethanes. In anticipation of the establishment of a MCL to be set forth by the Safe Drinking Water Act, chlorination may create problems. It is important, therefore, to consider some method of removing organics prior to disinfection or to consider alternatives to chlorination as a disinfectant. The following sections are intended to provide this evaluation.

TABLE 1

INPUT VARIABLE LIST - CHLORINATION

Variable	Definition
Q:	Average Daily Flow, MGD
DC12:	Dose of Chlorine, mg/ℓ
TC12:	Contact Time, minutes
CC12:	Cost of Chlorine, $/ton
ECF1:	Excess Capacity (contact basin)
ECF2:	Excess Capacity (chlorine feed system)
CCI:	Construction Cost Index
WPI:	Wholesale Price Index
DHR:	Direct Hourly Wage Rate, $/hr
PCT:	Percent of total overhead to be applied to chlorine treatment section of treatment plant
RI:	Amortization Interest Rate, percent
YRS:	Amortization Period, years
NCASE:	Number of Data Sets to be Run

TABLE 2

OUTPUT VARIABLE LIST - CHLORINATION

Variable	Definition
BVOL:	Basin Volume, cu. ft.
CUSE:	Chlorine Use, tons/yr.
CON:	Construction Cost, $
CAP:	Capital Cost, $
AMM	Debt Cost, ¢/1000 gal
O&M	Operations and Maintenance Cost, ¢/1000 gal
TOT	Total Cost, ¢/1000 gal

TABLE 3

STANDARDIZED VALUES USED FOR THE DETERMINATION OF SAMPLE COSTS - CHLORINATION

Average Daily Flow (Q)	7 mgd
Dose of Chlorine (DC12)	2 mg/ℓ
Contact Time (TC12)	20 minutes
Cost of Chlorine (CC12)	300 $/ton
Excess Capacity (ECF1 + ECF2)	1.43
* Construction Cost Index (CCI)/100	2.567
** Wholesale Price Index (WPI)/100	1.781
** Direct Hourly Wage Rate (DHR)	5.19 $/hr
Percent of Overhead (PCT)	.15
Amortization Interest Rate (RI)	.07
Amortization Period (YRS)	20 years

Plant operated at 70% capacity.

* March 1976

** Feb. 1976

TABLE 4

KEY FOR VARIABLE INPUT - CHLORINATION

Variable	Card	Columns	Comments
NCASE	1	1 & 2	This integer sets the number of cases to be run.
LIST	2	1-80	Alphanumeric title given to each case
Q	3	1-10	This variable and the subsequent ones may be placed anywhere within its allotted columns.
DCL2	3	11-20	
TCL2	3	21-30	
CCL2	3	31-40	
ECF1	3	41-50	
ECF2	3	51-60	
CCI	4	1-10	
WPI	4	11-20	
DHR	4	21-30	
PCT	4	31-40	
RI	4	41-50	
YRS	4	51-60	

Cards 2, 3 and 4 are repeated for each new case.

TABLE 5

CHLORINE COSTS ASSUMING STANDARDIZED DESIGN LEVELS

(¢/1000 gal)

	1 mgd			5 mgd			10 mgd			100 mgd			150 mgd		
	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost
Cl_2 Basin	.910	0.000	.910	.436	0.000	.436	.328	0.000	.328	.169	0.000	.169	.160	0.000	.160
Cl_2 Feed Basin	1.142	1.024	2.167	.385	.546	.932	.255	.452	.707	.075	.315	.390	.061	.304	.366
Total cost	2.053	1.024	3.077	.821	.546	1.368	.583	.452	1.035	.244	.315	.559	.220	.304	.526

CHLORINE DIOXIDE

Chlorine dioxide, since its inception as a potable water treatment agent in 1944, has been used almost exclusively in the post-treatment stage of the water treatment cycle. It is more expensive than chlorine, but displays a disinfectant ability comparable to chlorine and at a lower concentration in water. In cases where excess chloroform and other trihalomethanes are produced by chlorination (chlorine dioxide produces no trihalomethanes), the existing chlorination equipment can be modified to accommodate chlorine dioxide. However, the harmful byproducts, if any, resulting from use of chlorine dioxide are not known.

Tables 6 and 7 contain the program's input and output variables, respectively, together with the definitions for each variable. Table 8 contains standardized values for the design variables used in calculating costs. Table 9 is a key for inputting the variables into the program. Table 10 displays the costs associated with five different flow rates (all at 70% capacity). In the Appendix Figure 3A contains a listing of the program which was utilized for calculating the costs for chlorine dioxide. Figure 4A is a sample printout from the chlorine dioxide program utilizing values found in Table 8.

TABLE 6

INPUT VARIABLE LIST - CHLORINE DIOXIDE

Variable	Definition
Q:	Average Daily Flow, mgd
DC12:	Dose of Chlorine, mg/ℓ
TC12:	Contact Time, minutes
CC12:	Cost of Chlorine, $/ton
$CNClO_2$:	Cost of Sodium Chlorite, $/ton
RATIO:	Ratio of $NaClO_2$ to Cl_2
ECF 1-3:	Excess capacity for plant
CCI:	Construction Cost Index
WPI:	Wholesale Price Index
DHR:	Direct Hourly Wage Rate, $/hr
PCT:	Percent of Total Overhead to be applied to chlorine dioxide section of treatment plant
RI:	Amortization Interest Rate
YRS:	Amortization Period, years
FORK1:	Control variable for program (not presently used by program - it is set at 1)
NCASE:	Number of data sets program is to execute.

TABLE 7

OUTPUT VARIABLES - CHLORINE DIOXIDE

Variable	Definition
BVOL:	Basin Volume, cu ft
CUSE:	Chlorine Use, tons/yr
CNCUSE:	Sodium Chlorite Use, tons/yr
$CClO_2$:	Cost of Chlorine Dioxide, $/yr
CON:	Construction Cost, $
CAP:	Capital Cost, $
AMM:	Debt Cost, ¢/1000 gal
O&M:	Operations & Maintenance, ¢/1000 gal
TOT:	Total Cost, ¢/1000 gal

TABLE 8

STANDARDIZED VALUES USED FOR THE DETERMINATION

OF SAMPLE COSTS - CHLORINE DIOXIDE

Average Daily Flow (Q)	7 mgd
Dose of Chlorine (DC12)	.5 mg/l
Contact Time (TC12)	20 minutes
Cost of Chlorine (CC12)	300 $/ton
Cost of Sodium Chlorite ($CNC10_2$)	144 $/ton
Ratio of Sodium Chlorite to Chlorine (RATIO)	3.1:1
Excess Capacity (ECF1 + ECF2)	1.43
Program Control (FORK1)	1
* Construction Cost Index (CCI)/100	2.567
** Wholesale Price Index (WPI)/100	1.781
** Direct Hourly Wage Rate (DHR)	5.19 $/hr
Percent of Overhead (PCT)	.15
Amortization Interest Rate (RI)	.07
Amortization Period (YRS)	20 years

Plant run at 70% capacity.

Sodium Chlorite assumed 80% pure.

* March 1976

** Feb. 1976

TABLE 9

KEY FOR VARIABLE INPUT - CHLORINE DIOXIDE

Variable	Card	Columns	Comments
NCASE	1	1 & 2	This integer sets the number of cases to be run.
LIST	2	1-80	Alphanumeric title given to each case.
Q	3	1-10	This variable and the subsequent ones may be placed anywhere within its allotted columns.
DCL2	3	11-20	
TCC2	3	21-30	
CCL2	3	31-40	
CNC102	3	41-50	
RATIO	3	51-60	
ECF1	4	1-10	
ECF2	4	11-20	
ECF3	4	21-30	
FORK1	4	31-40	
CCI	5	1-10	
WPI	5	11-20	
DHR	5	21-30	
PCT	5	31-40	
RI	5	41-50	
YRS	5	51-60	

Card 2, 3, 4 and 5 are repeated for each new case

TABLE 10

CHLORINE DIOXIDE COSTS ASSUMING STANDARDIZED DESIGN LEVELS

(¢/1000 gal)

	1 mgd			5 mgd			10 mgd			100 mgd			150 mgd		
	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost
Cl_2 Basin	.911	0.000	.911	.436	0.000	.436	.328	0.000	.328	.170	0.000	.170	.160	0.000	.160
Cl_2 Feed Basin	.870	.577	1.448	.243	.231	.473	.150	.173	.323	.038	.093	.132	.031	.088	.119
$NaClO_2$ Cost	0.000	.933	.933	0.000	.933	.933	0.000	.933	.933	0.000	.933	.933	0.000	.933	.933
Total Cost	1.781	1.510	3.291	.679	1.164	1.842	.479	1.106	1.585	.208	1.027	1.235	.191	1.021	1.212

CHLORAMINATION

The use of chloramines as water disinfectants has been considered for water utilities presently using chlorine and finding unsatisfactory amounts of trihalomethanes in their product water. (Chloramines do not produce trihalomethanes.) Chloramines are generated by the reaction of chlorine and ammonia. The costs of converting to chloramine disinfection are low since existing chlorination equipment can easily be modified to produce chloramines.

Table 11 is a listing of input variables. Table 12 is a listing of output variables generated by the program. Table 13 contains standardized values for the design variables used in cost calculations. Table 14 is a key to variable input into the program. Table 15 displays the associated with five different flow rates (all at 70% capacity). In the appendix, Figure 5A contains a listing of the chloramine cost programs. Figure 6A is a sample printout from the program using standardized data. (Note: Construction, capital, and debt costs for the ammonia reactor are set to zero since they represent a small investment in relation to the entire chloramine system.)

TABLE 11

INPUT VARIABLE LIST - CHLORAMINES

Variable	Definition
Q:	Average Daily Flow, mgd
DC12:	Dose of Chlorine, mg/ℓ
TC12:	Contact Time, minutes
CC12:	Cost of Chlorine, $/ton
CNH3:	Cost of Ammonia, $/ton
RATIO:	Ratio of NH3 to Cl_2
ECF 1-3:	Excess capacity for plant
CCI:	Construction Cost Index
WPI:	Wholesale Price Index
DHR:	Direct Hourly Wage Rate, $/hr
PCT:	Percent of Total Overhead to be applied to chlorine dioxide section of treatment plant
RI:	Amortization Interest Rate
YRS:	Amortization Period, years
FORK1:	Control variable for program (not presently used by program - it is set at 1)
NCASE:	Number of data sets program is to execute.

TABLE 12

OUTPUT VARIABLES - Chloramines

Variable	Definition
BVOL:	Basin Volume, cu ft
CUSE:	Chlorine Use, tons/yr
NHSUSE:	Ammonia Use, tons/yr
CAMINE:	Cost of Chloramines, $/yr
CON:	Construction Cost, $
CAP:	Capital Cost, $
AMM:	Debt Cost, ¢/1000 gal
O+M:	Operations & Maintenance, c/1000 gal
TOT:	Total Cost, ¢/1000 gal

TABLE 13

STANDARDIZED VALUES USED FOR THE DETERMINATION

OF SAMPLE COSTS - CHLORAMINES

Average Daily Flow (Q)	7 mgd
Dose of Chlorine (DC12)	3.0 mg/ℓ
Contact Time (TC12)	20 minutes
Cost of Chlorine (CC12)	300 $/ton
Cost of Sodium Chlorite (CNH3)	200 $/ton
Ratio of Ammonia to Chlorine Conc. (RATIO)	1:5
Excess Capacity (ECF1 + ECF2)	1.43
Program Control (FORK1)	1
* Construction Cost Index (CCI)/100	2.567
** Wholesale Price Index (WPI)/100	1.781
** Direct Hourly Wage Rate (DHR)	5.19 $/hr
Percent of Overhead (PCT)	.15
Amortization Interest Rate (RI)	.07
Amortization Period (YRS)	20 years

Plant run at 70% capacity.

* March 1976

** Feb. 1976

TABLE 14

KEY FOR VARIABLE INPUT - CHLORAMINES

Variable	Card	Columns	Comments
NCASE	1	1 & 2	This integer sets the number of cases to be run.
LIST	2	1-80	Alphanumeric title given to each case.
Q	3	1-10	This variable and the subsequent ones may be placed anywhere within its allotted columns.
DCL2	3	11-20	
TCC2	3	21-30	
CCL2	3	31-40	
CNH3	3	41-50	
RATIO	3	51-60	
ECF1	4	1-10	
ECF2	4	11-20	
ECF3	4	21-30	
FORK1	4	31-40	
CCI	5	1-10	
WPI	5	11-20	
DHR	5	21-30	
PCT	5	31-40	
RI	5	41-50	
YRS	5	51-60	

Cards 2, 3, 4 and 5 are repeated for each new case

TABLE 15

CHLORAMINE COSTS ASSUMING STANDARDIZED DESIGN LEVELS

(¢/1000 gal)

	1 MGD			5 MGD			10 MGD			100 MGD			150 MGD		
	Capital	O&M	Total	Capital	O&M	Total	Capital	O&M	Total	Capital	O&M	Total	Capital	O&M	Total
Contact Basin	.911	0.00	.911	.436	0.00	.436	.328	0.00	.328	.170	0.00	.170	.160	0.00	.160
CCl_2 Feed System	1.279	1.276	2.556	0.452	0.730	1.182	0.304	0.619	0.923	0.092	0.457	0.549	0.075	0.445	0.520
NH_3 Reactor	0.00	0.050	0.050	0.00	0.050	0.050	0.00	0.050	0.050	0.00	0.050	0.050	0.00	0.050	0.050
Total	2.190	1.326	3.516	0.888	0.780	1.668	0.632	0.669	1.301	0.262	0.507	0.768	0.236	0.495	0.730

OZONATION

Another potable water treatment process that compares favorably in cost as well as disinfectant ability with chlorination and chlorine dioxide is ozonation. Ozone can be generated from air or bottled oxygen, air being slightly less expensive. The fact that the law requires a disinfectant residual remain in treated water, and ozone leaves none, necessitates an additional disfectant treatment stage. Therefore, along with the cost of ozonation, an additional cost for a residual disinfectant has to be considered. As with chlorine dioxide, the harmful byproducts, if any, caused by ozone are not known.

Tables 16 and 17 are listings of input and output variables and their definitions. Table 18 contains the standardized values used for the design variables. Table 19 is a key for inputting the variables into the program. Tables 20 and 21 contain the costs associated with five different flow rates (all at 70% capacity). In the appendix Figure 7A is a listing of the ozone cost program. Figures 8A and 9A are sample printouts from this program using the values found in Table 18.

TABLE 16

INPUT VARIABLE LIST - OZONE

Variable	Definition
DMATX(1,1) = DO3	Dose of ozone, mg/ℓ
DMATX(2,1) = DTO3	Contact time, minutes
DMATX (3,1) = Q	Average daily flow, mgd
DMATX (4,1) = CKWH	Cost of electrical power $/therm (1 term = 100,000 BTU)
DMATX (5,1) = EO3	Electrical power needed to generate ozone, kw-hr/lb
DMATX (6,1) = O2CST	Cost of liquid oxygen, $/lb
DMATX (7,1)= QP	Peak flow, mgd
DMATX (8,1) = TANKC	Cost of oxygen storage tank, $
DMATX (9,1) = FORK	Program control: 0 = ozonation by air; 1 = ozonation by oxygen
DMATX (10,1)	0
DMATX (11,1) to DMATX (12,1)	0
DMATX (13,1) = ECF	Excess capacity (oxygen storage tank)
DMATX (14,1) = ECF	Excess capacity (diffused air/oxygen system)
DMATX (15,1) = ECF	Excess capacity (aeration basin, covers, baffles)
DMATX (16,1) = ECF	Excess capacity (ozone regeneration facility)
CCI	Construction Cost Index
WPI	Wholesdale Price Index
DHR	Direct Hourly Wage Rate, $/hr
PCT	Percent of total overhead attributed to ozone treatment section of the water treatment plant
RI	Amortization interest rate, percent
YRS	Amortization period, years

TABLE 17

OUTPUT VARIABLES - OZONE

Variable	Definition
PPDO3:	Ozone production, lbs/day
VO3:	Reactor volume, 1000 cu ft
PPDO2:	Oxygen usage, lbs/day
DKWHR:	Electrical Power usage Kw-hr/day
ECOST:	Yearly cost of electrical power, $/yr
O2C:	Yearly cost of liquid O_2, $/yr
AF:	Amortization factor

DIFFUSED AIR SYSTEM

CFM:	Air usage, cu ft/min
OHRS:	Operations man-hours, hr/yr
TMSU:	Materials and supply cost, $/yr

TABLE 18

STANDARDIZED VALUES USED FOR THE

DETERMINATION OF SAMPLE COSTS - OZONE

Dose of Ozone (DO3)	1 mg/ℓ
Contact Time (DT03)	20 minutes
Average Daily Flow (Q)	7 mgd
Electrical Power Cost (CKWH)	.01 $/Therm
Electric Power Needed to Generate Ozone (EO3)	11 KWH/lb
* Cost of Liquid Oxygen (02CST)	.046 $/lb
Peak Capacity for Plant (QP)	10 mgd
* Cost for Oxygen Storage Tank (TANKC)	37000. $
** Program Control (FORK1)	either 1 or 0
Excess Capacity (ECF 1-4)	1.0
Construction Cost Index (CCI)/100	2.567
Wholesale Price Index (WPI)/100	1.781
Direct Hourly Wage Rate (DHR)	5.19 $/hr
Percent of Overhead (PCT)	.15
Amortization Interest Rate (RI)	.07
Amortization Period (YRS)	20 years

Plant Run at 70% Capacity

* These variables only have values when ozone is generated from oxygen.

** See variable definitions.

TABLE 19

KEY FOR VARIABLE INPUT - Ozone

Variable	Card	Columns	Comments
NCASE	1	1 & 2	This integer sets the number of cases to be run.
LIST	2	1-80	Alphanumeric title given to each case.
DO3	3	1-8	This variable and the subsequent ones may be placed anywhere within its allotted columns.
DTO3	3	9-16	
Q	3	17-24	
CKWH	3	25-32	
EO3	3	33-40	
O2CST	3	41-48	
QP	3	49-56	
TANKC	3	57-64	
FORK	3	65-72	
	4	1-8	No variable corresponds to this position. Zero has to be read in.
	4	9-16	Same as above
ECF1	4	17-24	
ECF2	4	25-32	
ECF3	4	33-40	
ECF4	4	41-48	
	4	49-56	See comment at beginning of card 4.
	4	57-64	"
	4	65-72	"
CCI	5	1-10	
WPI	5	11-20	
DHR	5	21-30	
PCT	5	31-40	
RI	5	41-50	
YRS	5	51-60	

Cards 2, 3, 4 and 5 are repeated for each new case.

TABLE 20

OZONE (AIR) COSTS ASSUMING STANDARDIZED DESIGN LEVELS

(c/1000 gal)

	1 mgd			5 mgd			10 mgd			100 mgd			150 mgd		
	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost
Ozone Generating Facilities	.563	.091	0.654	.474	.901	.566	.440	.091	.532	.345	.091	.436	.330	.091	.422
Aeration Basin Covers, Baffles	1.244	0.000	1.244	.486	0.000	.486	.372	0.000	.372	.236	0.000	.236	.229	0.000	.229
Diffused Air System	.0769	3.672	4.441	.183	1.034	1.217	.112	.629	.741	.033	.145	.178	.028	.115	.143
O_2 Storage Tank	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total Cost	2.576	3.764	6.340	1.143	1.126	2.269	.924	.721	1.645	.613	.237	.850	.587	.206	.793

TABLE 21

OZONE (OXYGEN) COSTS ASSUMING STANDARDIZED DESIGN LEVELS

(c/1000 gal)

	1 mgd			5 mgd			10 mgd			100 mgd			150 mgd		
	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost
Ozone Generating Facilities	.303	.091	.395	.255	.091	.347	.237	.329	.329	.185	.091	.277	.178	.091	.269
Aeration Basin Covers, Baffles	1.244	0.000	1.244	.486	0.000	.486	.372	0.000	.372	.236	0.000	.236	.229	0.000	.229
Diffused Air System	.769	3.672	4.44.	.183	1.034	1.217	.112	.629	.741	.033	.145	.178	.028	.115	.143
O_2 Storage Tank	1.528	0.075	1.603	.364	.115	.479	.216	.115	.332	.064	.115	.180	.056	.115	.171
Total Cost	3.844	3.839	7.683	1.288	1.241	2.529	.938	.836	1.774	.519	.352	.870	.491	.321	.812

GRANULAR ACTIVATED CARBON

The use of granular activated carbon (GAC) for treatment of potable water (even when used at a large water utility at a high capacity factor) is an expensive treatment process. The addition of a disinfectant (i.e., chlorine) at some stage in the treatment cycle would further increase the cost associated with GAC. Therefore, the use of GAC is economically justifiable when the use of less costly and effective treatments cannot produce the quality of potable water required by the law and demanded by the public.

The GAC plant is divided into two operational processes.[7] In the first process (treatment stage), water is pumped through the carbon contactors. Microscopic pores in the activated carbon act to adsorb the impurities in the water. The second process involves the reactivation of the activated carbon once it passes a predetermined point in its treatment life. The program in Figure 10A (appendix) is designed to estimate reactivation costs at the water utility site. This situation, in test runs, has produced excessively high costs for smaller water utilities due to the great bulk of the cost for GAC treatment in smaller plants which lies in the reactivation process. However, a group of small waterworks could collectively share in a regional reactivation facility. This regional facility could substantially reduce the excessive costs resulting from on-site reactivation.[8]

Tables 22 and 23 are input and output variables and their definitions. Table 24 contains a set of standardized values for the design variables in this program. Table 25 is a key for variable input and Table 26 contains costs for plants of 1, 5, 10, 100, and 150 mgd, all operating at 70% of capacity. Figure 10A is a listing of the GAC Program and Figure 11A is a sample printout of the GAC program using values found in Table 24.

Two calculations are required in order to be able to input variables to the program. These calculations are for DCARB and RRATE and they are as follows:

$$\text{RRATE} = \frac{\text{\# of contactors (CONTN)} \times 865\ \text{ft}^9/\text{contactor} \times 30\ \text{lb/ft}^3\ \text{wt. of gran. carbon}}{1.4\ \text{month reactivation} \times 30\ \text{days/month}}$$

$$\text{GCARB} = \frac{\text{\# of contactors (CONTN)} \times 865\ \text{ft}^3/\text{contactor} \times 30\ \text{lb/ft}^3}{1.4\ \text{month reactivation}^* \times 30\ \text{days/month} \times \text{QD}}$$

---

* provided FORK1 = 1

** The reactivation rate for GAC may also be used as a variable and its effect will be a change in DCARB and RRATE.

TABLE 22

INPUT VARIABLE LIST - GAC

Variable	Definition
QD:	Average daily volume flow used for design of system, mgd
QP:	Peak flow, mgd
RI:	Amortization Interest Rate, fraction
YRS:	Amortization Period, years
CCI:	Sewage Treatment Plant Construction Cost Index
WPI:	Wholesale Price Index
FORK1:	Program Control: 0 = number (CONTN) and size (VOLI) of the carbon contactors is to be calculated by the program, 1 = number and size are program inputs
FORK2:	Program Control: 0 = furnace size (HAREH) of the carbon reactivation system is to be calculated by the program, 1 = furnace size is program input.
DCARB:	Design carbon reactivation rate, lbs/mil gal
RRATE:	Design carbon reactivation rate, lbs/day
HAREA:	Hearth area for carbon reactivation (if not to be calculated by the program), sq ft
HLOAD:	Hydraulic surface loading on the carbon contactors (not needed if CONTN & VOLI are program inputs), gpm/ sq ft
CDIAM:	Diameter of the carbon contactors (not needed if CONTN & VOLI are program inputs)
SERN:	Number of carbon contactors in series (not needed if CONTN & VOLI are program inputs).
CT:	Carbon contact time, minutes
CTYPE:	Program control for type of carbon contactors installed (not presently used by program)

TABLE 22 (Cont.)

Variable	Definition
POWER:	Electrical Power Cost, $/KWH
DHR:	Direct Hourly Wage Rate, $/hr
FUEL:	Fuel cost, $/therm 1 therm = 100,000 BTU
CARBC:	Cost of virgin granular carbon, $/lb
CARBM:	Carbon make-up, fraction/yr
PUMPF:	Fraction of pumping station cost charged to carbon adsorption when operating filters and carbon contactors in series, fraction
CONTN:	Number of carbon contactors used (not needed if program is calculate CONTN)
VOLI:	Volume of each carbon contactor (not needed if program is to calculate VOLI), cu ft
NCASE:	Number of data sets program is to execute

TABLE 23

OUTPUT VARIABLE LIST - GAC

Variable	Definition
COHRS:	Carbon contactor operation labor required, hours/years
CMHRS:	Carbon contactor maintenance labor required, hours/year
CLHRS:	Carbon contactor laboratory labor required, hours/year
CTHRS:	Carbon contactor total labor requirement, hours/year
CLAB:	Yearly labor cost for carbon contactors, $/year
CMATM:	Yearly maintenance materials cost for carbon contactors, $/year
CMATP:	Yearly electrical power cost for carbon contactors, $/year
CTOT:	Total yearly operation and maintenance cost for carbon contactors, $/year
ROHRS:	Carbon reactivation operation labor required, hours/year
RMHRS:	Carbon reactivation maintenance labor required, hours/year
RLHRS:	Carbon reactivation laboratory labor required, hours/year
RTHRS:	Carbon reactivation total labor requirement, hours/year
RLAB:	Yearly labor cost for carbon reactivation, $/year
RMATM:	Yearly maintenance materials cost for carbon reactivation, $/year
RMATP:	Yearly electrical power cost for carbon reactivation, $/year
RMATF:	Yearly fuel cost for carbon reactivation, $/year
RMATC:	Yearly makeup carbon cost for carbon reactivation, $/year
RTOT:	Total yearly operation and maintenance cost for carbon reactivation, $/year
CONTN:	Number of carbon contactors used (as input or computed by program)
TAREA:	Total surface area of all carbon contactors, sq ft
CAREA:	Surface area of each carbon contactor, sq ft
CLENG:	Effective carbon column length, ft
TVOL:	Total effective colume of all carbon contactors used, cu ft
VOL1:	Volume of each carbon contactor (as input or computed by program), cu ft

TABLE 24

STANDARDIZED VALUES USED FOR THE DETERMINATION OF SAMPLE COSTS

Average Daily Flow (QD)	7 mgd
Peak Flow (QP)	10 mgd
Amortization Interest Rate (RI)	.07
Amortization Period (YRS)	20 years
* Construction Cost Index (CCI)/100	2.567
** Wholesale Price Index (WPI)/100	1.781
Program Control (FORK1)	1
Program Control (FORK2)	0
Design Carbon Regeneration Rate (DCARB)	882.65 lbs/mil gal
Design Carbon Regeneration Rate (RRATE)	6178.57 lbs/day
Hearth Area (HAREA)	0.
Hydraulic Surface Loading (HLOAD)	0.
Diameter of Carbon Contactors (CDIAM)	0.
Number of Carbon Contactors (SERN)	0.
Carbon Contact Time (CT)	4.5 min
Program Control (not presently used) (CTYPE)	0.
Electrical Power Cost (POWER)	.01 $/KWH
** Direct Hourly Wage Rate (DHR)	5.19 $/hr
Fuel Cost (FUEL)	.26 $/therm
Cost of Virgin Carbon (CARBC)	.38 $/lb
Carbon Make-up (CARBM)	.1
Fraction of Pumpint Station Cost (PUMPF)	0.
Number of Carbon Contactors Used (CONTN)	10
Volume of Each Carbon Contactor (VOLI)	865 cu ft
Excess Capacity (ECF 1-4)	1.0

*March 1976

**February 1976

TABLE 25

KEY FOR VARIABLE INPUT - GAC

Variable	Card	Columns	Comments
NCASE	1	1 & 2	This integer sets the number of cases to be run.
LIST	2	1-80	Alphanumeric title given to each case
QD	3	1-10	This variable and the subsequent ones may be placed anywhere within their allotted columns.
QP	3	11-20	
RI	3	21-30	
YRS	3	31-40	
CCI	3	41-50	
WPI	3	51-60	
FORK1	3	61-70	
FORK2	3	71-80	
DCARB	4	1-10	
RRATE	4	11-20	
HAREH	4	21-30	
HLOAD	4	31-40	
CDIAM	4	41-50	
SERN	4	51-60	
CT	4	61-70	
CTYPE	4	71-80	
POWER	5	1-10	
DHR	5	11-20	
FUEL	5	21-30	
CARBC	5	31-40	
CARBM	5	41-50	
PUMPF	5	51-60	
CONTN	5	61-70	
VOL1	5	71-80	
ECF1	6	1-10	
ECF2	6	11-20	
ECF3	6	21-30	
ECF4	6	31-40	

TABLE 26

GRANULAR ACTIVATED CARBON COSTS ASSUMING DESIGN LEVELS

(c/1000 gal)

	1 mgd			5 mgd			10 mgd			100 mgd			150 mgd		
	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost	Capital Cost	O&M Cost	Total Cost
Influent Pump Station	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Carbon Contactors	5.264	1.850	7.114	5.234	1.002	6.237	5.209	.817	6.026	5.113	.521	5.634	5.096	.495	5.590
Carbon Reactivation System	21.654	21.523	43.177	4.307	10.655	43.177	2.904	8.237	11.140	.812	4.462	5.275	.649	4.158	4.807
Initial Carbon Charge	.691	0.000	.691	.687	0.000	.687	.684	0.000	.684	.671	0.000	.671	.669	0.000	.669
Total	27.610	23.373	50.983	10.228	11.657	21.886	8.796	9.054	17.850	6.597	4.983	11.580	6.414	4.653	11.067
Total Less Carbon Contactors Cost	22.345	21.523	43.868	4.994	10.655	15.649	3.588	8.237	11.824	1.483	4.462	5.945	1.318	4.158	5.476

APPLICATIONS

The programs contained in this document can be used to explore many important relationships with regard to water treatment systems. Examples of the uses to which these programs can be put is contained in the following discussion. The first three examples deal only with the use of Granular Activated Carbon. The last example illustrates the use of two of the programs to synthesize a Biological Activated Carbon System.

Several economic relationships can be explored with regard to the operation of GAC systems. One is the effect of reactivation frequency. Figure 1 shows the total unit cost of a 100 MGD GAC sand replacement system versus the period between reactivations. As can be seen from the figure, costs escalate rapidly when the period between reactivations is shortened.

An important economic option, particularly for small systems, is that of banding together, either as a group of small systems or with a larger system to minimize the cost of regeneration. Figure 2 shows the tradeoffs that exist between hauling activated carbon to a central reactivation site furnish versus onsite reactivation. In this case, it is hypothesized that a group of ten 10MGD utilities have joined together to provide regional reactivation services and are sharing the cost of a regional reactivation furnace jointly.

The effect of changes in the level of inflation on GAC costs is highly significant. To illustrate this effect, the cost for a 100 MGD sand replacement system have been assumed at 9.0¢/1000 gal at year 0 and

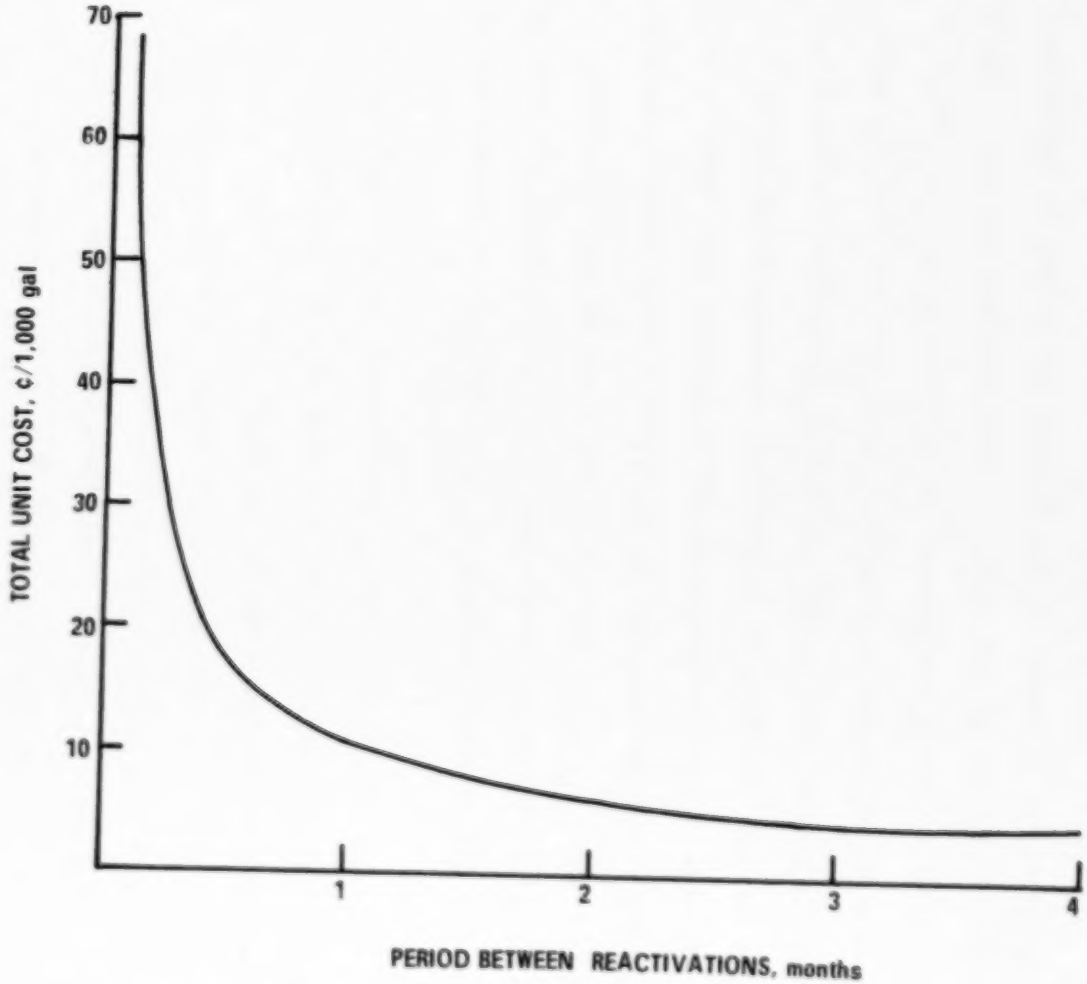

Figure 1. COST FOR 100 MGD SAND REPLACEMENT SYSTEM BASED ON REACTIVATION FREQUENCY

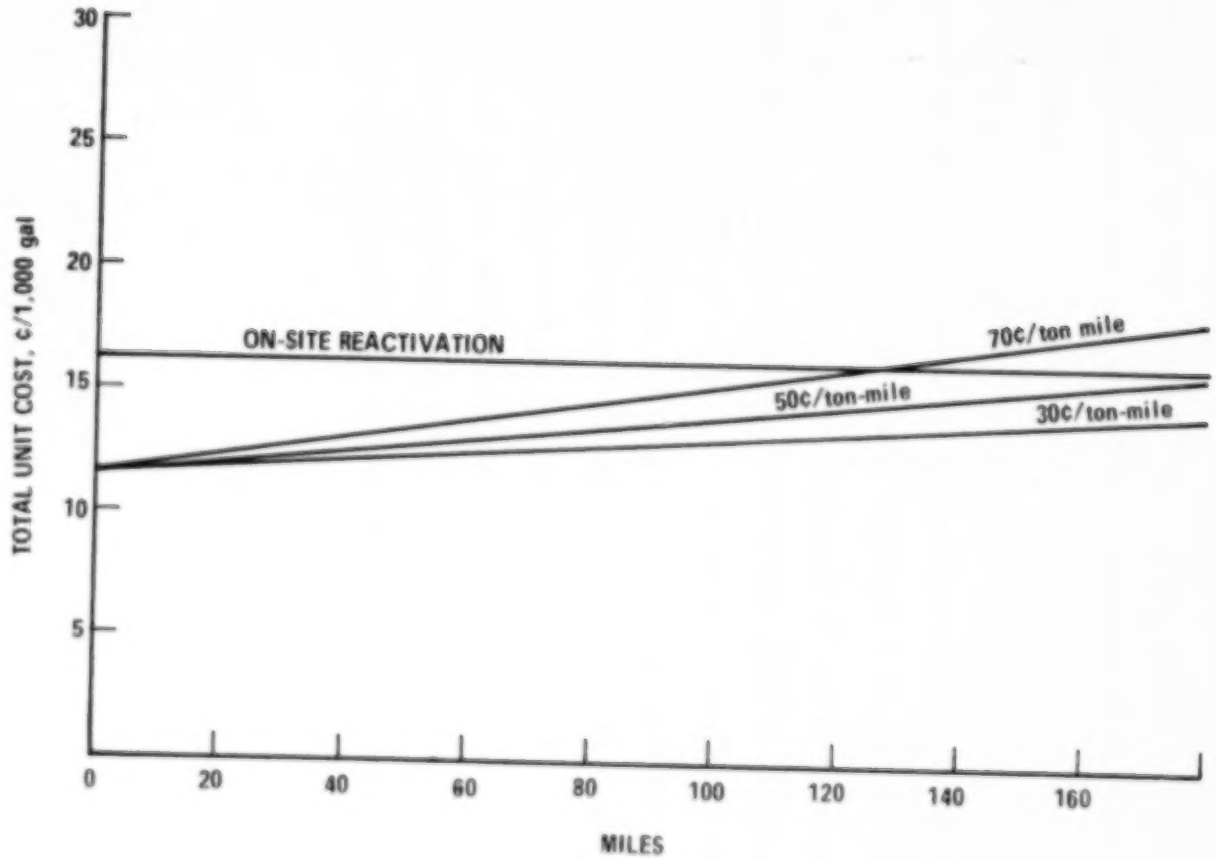

Figure 2.-TRANSPORTATION COST VERSUS ON-SITE REACTIVATION

then allowed to increase at 6% per year for 10 years. At the end of the 10 year period the unit cost has increased from 9.0¢/1000 gal in year 0 to over 20¢/1000 gal in year 10, as shown in Figure 3.

For systems requiring high carbon loading rates and short reactivation periods, there is the possibility of combing processes together to minimize costs. One such combination is ozonation and GAC used to form a biological activated carbon (BAC) system. In this type of system, the water is ozonated before it is placed on the activated carbon bed and biological action takes place on or near the surface of the bed. Organics are broken down, biological growth is encouraged, and biodegradtion aids adsorption. Dramatic increases in the period between reactivation have been reported using this technique. From Figure 1 it can be seen that lengthening the period between reactivation can reduce costs dramatically. Figure 4 shows a set of hypothetical cost curves for BAC versus GAC. Assming the GAC system has a period between reactivations of 1.1 months and cost 14¢/1000 gal. If an ozone dosage of 2 mg/l can increase the period between reactivations from 1.1 months to 2 months or greater, cost savings can be realized. Research is continuing on the use of this approach to minimize costs.

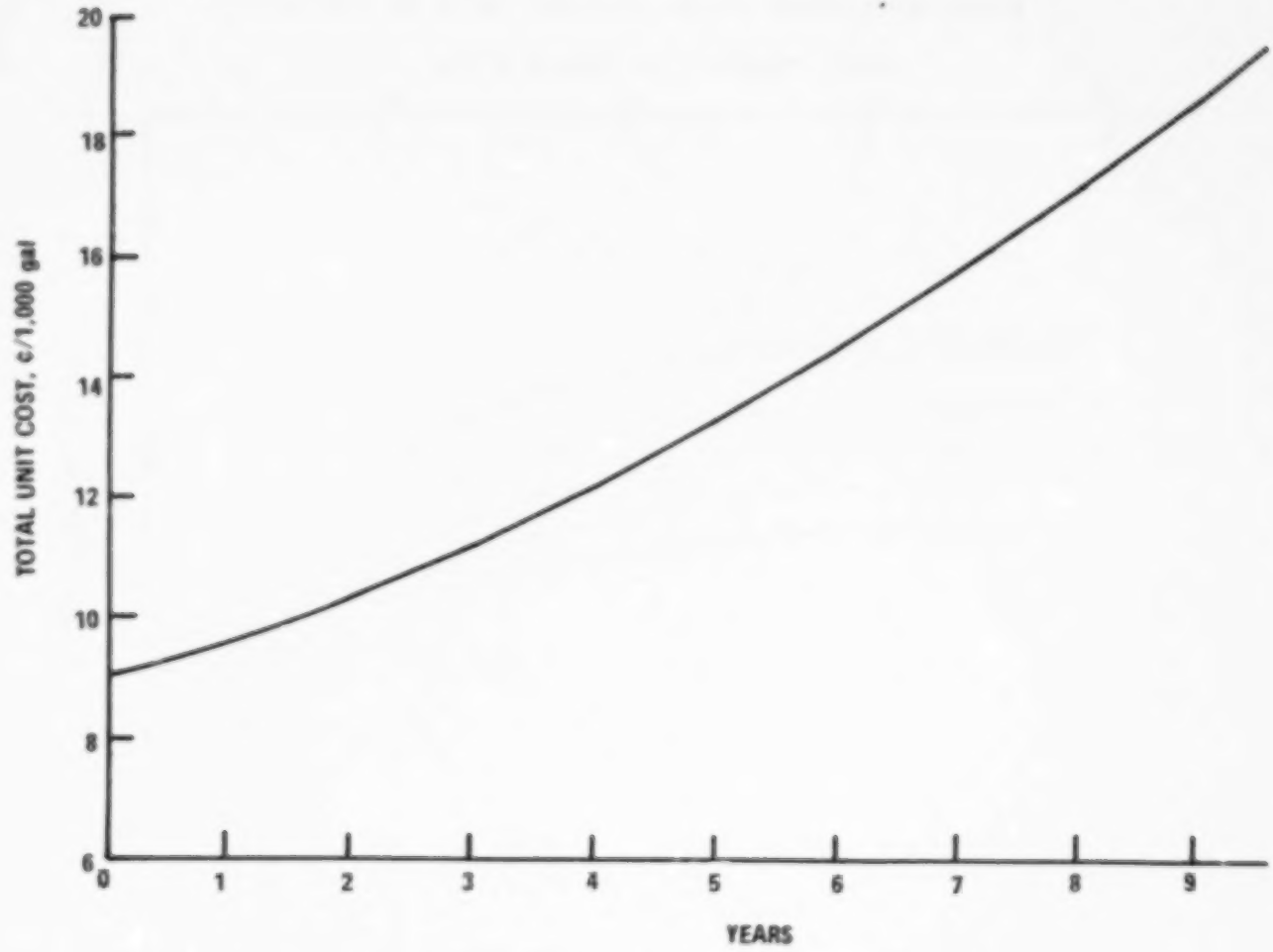

Figure 3. EFFECT OF 6% INFLATION ON TOTAL UNIT COST FOR SAND REPLACEMENT SYSTEM

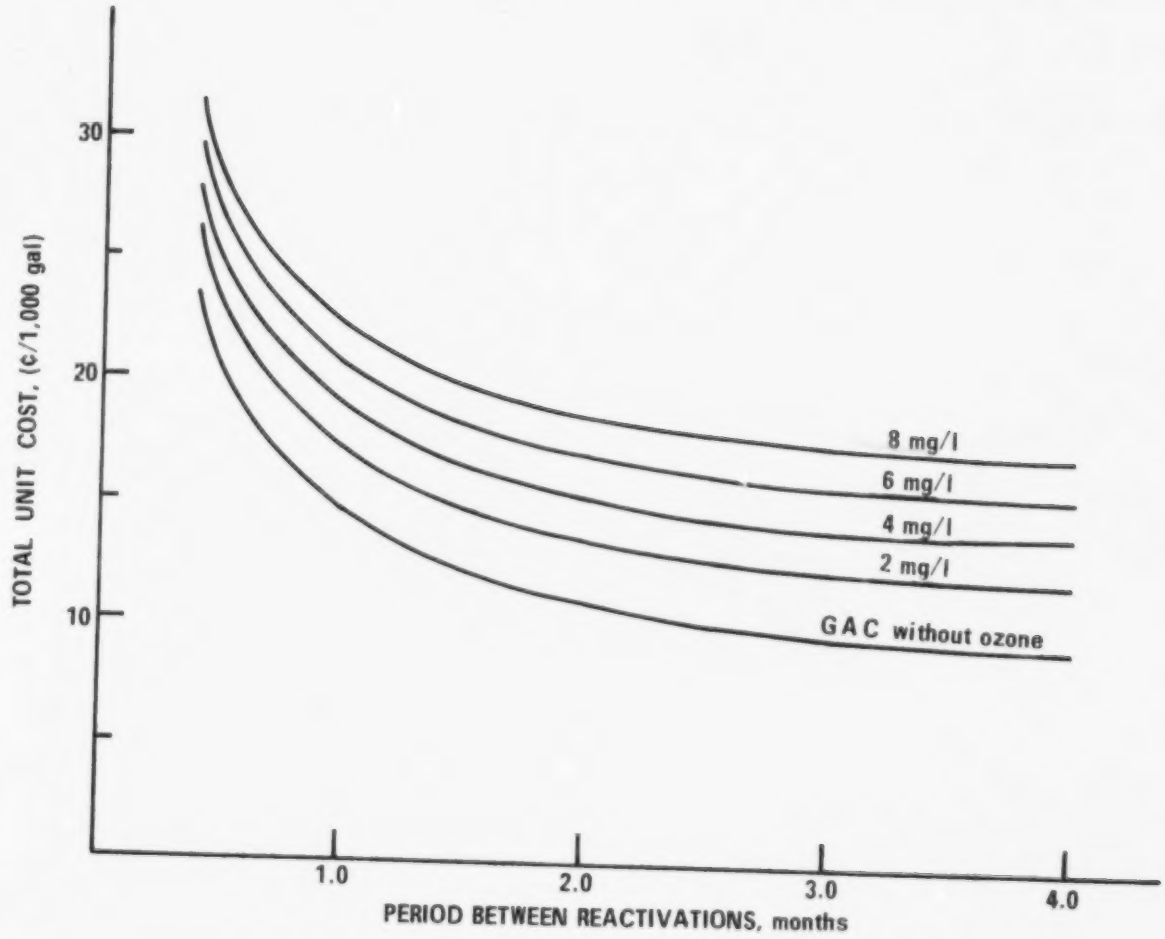

Figure 4. COST OF OZONE AND GAC VERSUS REACTIVATION PERIOD

SUMMARY AND CONCLUSIONS

An increasing awareness of the potential health hazards associated with the public's drinking water is now being evidenced throughout the country. This awareness has caused traditional methods by which water is made potable to come under severe scrutiny. Alternate types of water treatment have been shown to reduce dangerous pollutants and contaminants in water while at the same time compare favorably in cost with traditional treatment practices. Still other water treatment processes, while comparatively expensive, can improve water quality significally in highly polluted sources. The treatment system utility used not only depends upon intrinsic factors relating to the utility itself and the water source, but also the cost of the finished product. The cost of inadequately produced water can be estimated; the cost this water has on the public's health cannot.

REFERENCES

1. Patterson, W. L., and Banker, R. F., Estimating Costs and Manpower Requirements of Conventional Wastewater Treatment Facilities for the Environmental Protection Agency, Black and Veatch, Consulting Engineers, Kansas City, Missouri, 1971.

2. Clark, Robert M., Guttman, Daniel L., Crawford, John L., and Machisko, John A., The Cost of Removing Chloriform and Other Trihalomethanes from Drinking Water Supplies, USEPA, MERL, Cincinnati, Ohio, 1976.

3. Ibid., Robert M. Clark.

4. Safe Drinking Water Act, Public Law 93-523, 93rd Congress, S.433, December 16, 1974.

5. Suindell-Dressler Company, "Process Design Manual for Carbon Absorption", USEPA Technology Transfer, October 1973.

6. Robert M. Clark, loc cit.

7. Eilers, Richard M., Mathematical Models for Calculating Performance and Cost of Wastewater Treatment Systems, Environmental Modeling and Simulation, U. S. Environmental Protection Agency, 1976.

APPENDIX

Reproduced from best available copy.

Figure 1A. Listing of chlorine cost program

```
C     (CL2N2)    COST OF CHLORINATION
      DIMENSION LIST(40)
      OPEN(UNIT=1,NAME='CL2.DAT',TYPE='OLD')
      IN=1
      IO=6
      READ(IN,10) NCASE
   10 FORMAT(I2)
      DO 200 III=1,NCASE
      READ(IN,30) LIST
   30 FORMAT(40A2)
      READ(IN,40) Q,DCL2,TCL2,CCL2,ECF1,ECF2
      READ(IN,40) CCI,WPI,DHR,PCT,RI,YRS
   40 FORMAT(8F10.0)
      CCI=CCI/1.506
      WPI=WPI/1.122
      AF=RI*(1.+RI)**YRS/((1.+RI)**YRS-1.)
      BVOL=Q*TCL2/1.44/7.48*1000.*ECF1
      X=ALOG(BVOL/1000.)
      CON1=EXP(2.048061+.521909*X-.002674*X**2+.004159*X**3)*1000.*CCI
      CAP1=CON1*1.35
      AMM1=CAP1*AF/Q/3650.
      OMC1=0.
      TOT1=AMM1+OMC1
      CUSE=Q*DCL2*8.33*365./2000.
      X=ALOG(CUSE*2000./365.*ECF2)
      XCOST=EXP(2.264294-.044271*X+.065029*X**2-.002536*X**3)*1000.
      CON2=XCOST*CCI
      CAP2=CON2*1.35
      AMM2=CAP2*AF/Q/3650.
      X=ALOG(CUSE)
      OHRS=EXP(4.538517+.543669*X)
      XMHRS=EXP(3.752071-.224812*X+.158849*X**2-.006064*X**3)
      TMSU=EXP(6.126105+.287016*X)*WPI
      TMSUC=CUSE*CCL2+TMSU
      OMC2=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSUC)/Q/3650.
      TOT2=AMM2+OMC2
      T1=CON1+CON2
      T2=CAP1+CAP2
      T3=AMM1+AMM2
      T4=OMC1+OMC2
      T5=TOT1+TOT2
      CCI=CCI*1.506
      WPI=WPI*1.122
      WRITE(IO,100) LIST
  100 FORMAT(1H1,40A2,/)
      WRITE(IO,110) Q,DCL2,TCL2,CCL2,ECF1,ECF2
  110 FORMAT(9X,'Q',8X,'DCL2',8X,'TCL2',8X,'CCL2',8X,'ECF1',8X,
     . 'ECF2',/,6F12.3,/)
      WRITE(IO,114) CCI,WPI,DHR,PCT,RI,YRS
  114 FORMAT(7X,'CCI',9X,'WPI',9X,'DHR',9X,'PCT',10X,'RI',9X,
     . 'YRS',/,6F12.3,//)
      WRITE(IO,120) BVOL,CUSE
  120 FORMAT(6X,'BVOL',8X,'CUSE',8X,/,2F12.3,//)
      WRITE(IO,130)
  130 FORMAT(27X,'CON',9X,'CAP',9X,'AMM',9X,'O+M',9X,'TOT',9X,'ECF',/)
      WRITE(IO,132) CON1,CAP1,AMM1,OMC1,TOT1,ECF1
  132 FORMAT(2X,'CONTACT BASIN',5X,2F12.0,3F12.3,F12.2)
      WRITE(IO,134) CON2,CAP2,AMM2,OMC2,TOT2,ECF2
  134 FORMAT(2X,'CL2 FEED SYSTEM',3X,2F12.0,3F12.3,F12.2,/)
      WRITE(IO,140) T1,T2,T3,T4,T5
  140 FORMAT(2X,'TOTAL',13X,2F12.0,3F12.3)
  200 CONTINUE
      END
```

Figure 2A. Sample printout from chlorine cost program

10 MGD CHLORINE TREATMENT PLANT

Q	DCL2	TCL2	CCL2	ECF1	ECF2
7.000	2.000	20.000	300.000	1.430	1.430

CCI	WPI	DHR	PCI	RI	YRS
2.567	1.781	5.190	0.150	0.070	20.000

BVOL	CUSE
18586.600	21.283

	CON	CAP	AMM	O+M	TOT	ECF
CONTACT BASIN	65862.	88913.	0.328	0.000	0.328	1.43
CL2 FEED SYSTEM	51100.	68985.	0.255	0.452	0.707	1.43
TOTAL	116962.	157899.	0.583	0.452	1.035	

Figure 3A. Listing of chlorine dioxide cost program

```
C     (CLO2)      COST ESTIMATE OF CHLORINE DIOXIDE  WATER TREATMENT
      DIMENSION LIST(40)
      OPEN(UNIT=1,NAME='CLO2.DAT',TYPE='OLD')
      IN=1
      IO=6
      READ(IN,10) NCASE
   10 FORMAT(I2)
      DO 1000 III=1,NCASE
      READ(IN,30) LIST
   30 FORMAT(40A2)
      READ(IN,40) Q,DCL2,TCL2,CCL2,CNCLO2,RATIO
      READ(IN,40) ECF1,ECF2,ECF3,FORK1
      READ(IN,40) CCI,WPI,DHR,PCT,RI,YRS
   40 FORMAT(8F10.0)
      CCI=CCI/1.506
      WPI=WPI/1.122
      AF=RI*(1.+RI)**YRS/((1.+RI)**YRS-1.)
      BVOL=Q*TCL2/1.44/7.48*1000.*ECF1
      X=ALOG(BVOL/1000.)
      CON1=EXP(2.048061+.521909*X-.002674*X**2+.004159*X**3)*1000.*CCI
      CAP1=CON1*1.35
      AMM1=CAP1*AF/Q/3650.
      OMC1=0.
      TOT1=AMM1+OMC1
      CUSE=Q*DCL2*8.33*365./2000.
      X=ALOG(CUSE*2000./365.*ECF2)
      CON2=EXP(2.264294-.044271*X+.065029*X**2-.002536*X**3)*1000.*CCI
      CAP2=CON2*1.35
      AMM2=CAP2*AF/Q/3650.
      X=ALOG(CUSE)
      OHRS=EXP(4.538517+.543669*X)
      XMHRS=EXP(3.752071-.224812*X+.158849*X**2-.006064*X**3)
      TMSU=EXP(6.126105+.287016*X)*WPI
      TMSUC=CUSE*CCL2+TMSU
      OMC2=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSUC)/Q/3650.
      TOT2=AMM2+OMC2
      CNCLO2=DCL2*RATIO
      DCLO2=CNCLO2/1.68
      CNUSE=Q*CNCLO2*8.33*365./2000.
      IF(FORK1) 50,50,60
   50 CONTINUE
   60 CON3=0.
      CAP3=0.
      AMM3=0.
      OMC3=CNCLO2*CNUSE/Q/3650.
      CCLO2=CNCLO2*CNUSE+CCL2*CUSE
      TOT3=AMM3+OMC3
      T1=CON1+CON2+CON3
      T2=CAP1+CAP2+CAP3
      T3=AMM1+AMM2+AMM3
      T4=OMC1+OMC2+OMC3
      T5=TOT1+TOT2+TOT3
      CCI=CCI*1.506
      WPI=WPI*1.122
      WRITE(IO,100) LIST
  100 FORMAT('1',///////,40A2,/)
      WRITE(IO,110) Q,DCL2,TCL2,CCL2,CNCLO2,RATIO
  110 FORMAT(/,T18,'Q',T26,'DCL2',T36,'TCL2',T46,'CCL2',T54,'CNCLO2',
     AT65,'RATIO',/,T11,6F10.3)
      WRITE(IO,130) CCI,WPI,DHR,PCT,RI,YRS,FORK1
  130 FORMAT(//,T17,'CCI',T27,'WPI',T37,'DHR',T47,'PCT',T58,'RI',T67,
     C'YRS',T75,'FORK1',/,T11,7F10.3)
      WRITE(IO,140) BVOL,CUSE,CNUSE,CCLO2,DCLO2
  140 FORMAT(//,T17,'BVOL',T29,'CUSE',T40,'CNUSE',T52,'CCLO2',T64,
     D'DCLO2',/,8X,5F12.3,//)
      WRITE(IO,150)
  150 FORMAT(27X,'CON',9X,'CAP',9X,'AMM',9X,'O+M',9X,'TOT',9X,'ECF',/)
      WRITE(IO,160) CON1,CAP1,AMM1,OMC1,TOT1,ECF1
  160 FORMAT(2X,'CONTACT BASIN',5X,2F12.0,3F12.3,F12.2)
      WRITE(IO,170) CON2,CAP2,AMM2,OMC2,TOT2,ECF2
  170 FORMAT(2X,'CL2 FEED SYSTEM',3X,2F12.0,3F12.3,F12.2)
      WRITE(IO,180) CON3,CAP3,AMM3,OMC3,TOT3,ECF3
  180 FORMAT(2X,'CLO2 REACTOR',6X,2F12.0,3F12.3,F12.2,/)
      WRITE(IO,190) T1,T2,T3,T4,T5
  190 FORMAT(2X,'TOTAL',13X,2F12.0,3F12.3)
 1000 CONTINUE
      END
```

Figure 4A. Sample printout from chlorine dioxide cost program

10 MGD CHLORINE DIOXIDE TREATMENT PLANT

Q	DCL2	TCL2	CCL2	CNCLO2	RATIO
7.000	0.500	20.000	300.000	1400.000	3.200

CCI	WPI	DHR	PCT	RI	YRS	FORK1
2.567	1.781	5.190	0.150	0.070	20.000	1.000

BVOL	CUSE	CNUSE	CCLO2	DCLO2
18586.600	5.321	17.027	25433.363	0.952

	CON	CAP	AMM	O+M	TOT	ECF
CONTACT BASIN	65862.	88913.	0.328	0.000	0.328	1.43
CL2 FEED SYSTEM	30135.	40682.	0.150	0.173	0.323	1.43
CLO2 REACTOR	0.	0.	0.000	0.933	0.933	1.43
TOTAL	95997.	129595.	0.479	1.106	1.585	

Figure 5A. Listing of chloramine cost program

```
C          COST ESTIMATE OF WATER TREATMENT BY CHLORAMINES
      REAL NH3USE
      DIMENSION LIST(40)
      OPEN(UNIT=1,NAME='AMMON.DAT',TYPE='OLD')
      IN=1
      IO=6
      READ(IN,10) NCASE
   10 FORMAT(I2)
      DO 1000 III=1,NCASE
      READ(IN,30) LIST
   30 FORMAT(40A2)
      READ(IN,40) Q,DCL2,TCL2,CCL2,CNH3,RATIO
      READ(IN,40) ECF1,ECF2,ECF3,FORK1
      READ(IN,40) CCI,WPI,DHR,PCT,RI,YRS
   40 FORMAT(8F10.0)
      CCI=CCI/1.506
      WPI=WPI/1.122
      AF=RI*(1.+RI)**YRS/((1.+RI)**YRS-1.)
      BVOL=Q*TCL2/1.44/7.48*1000.*ECF1
      X=ALOG(BVOL/1000.)
      CON1=EXP(2.048061+.521909*X-.002674*X**2+.004159*X**3)*1000.*CCI
      CAP1=CON1*1.35
      AMM1=CAP1*AF/Q/3650.
      OMC1=0.
      TOT1=AMM1+OMC1
      CUSE=Q*DCL2*8.33*365./2000.
      X=ALOG(CUSE*2000./365.*ECF2)
      CON2=EXP(2.264294-.044271*X+.065029*X**2-.002536*X**3)*1000.*CCI
      CAP2=CON2*1.35
      AMM2=CAP2*AF/Q/3650.
      X=ALOG(CUSE)
      OHRS=EXP(4.538517+.543669*X)
      XMHRS=EXP(3.752071-.224812*X+.158849*X**2-.006064*X**3)
      TMSU=EXP(6.126105+.287016*X)+WPI
      TMSUC=CUSE*CCL2+TMSU
      OMC2=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSUC)/Q/3650.
      TOT2=AMM2+OMC2
      CNH3=DCL2/RATIO
      NH3USE=Q*CNH3*8.33*365./2000.
      IF(FORK1) 50,50,60
   50 CONTINUE
   60 CON3=0.
      CAP3=0.
      AMM3=0.
      OMC3=CNH3*NH3USE/Q/3650.
      CAMINE=CNH3*NH3USE+CCL2*CUSE
      TOT3=AMM3+OMC3
      T1=CON1+CON2+CON3
      T2=CAP1+CAP2+CAP3
      T3=AMM1+AMM2+AMM3
      T4=OMC1+OMC2+OMC3
      T5=TOT1+TOT2+TOT3
      CCI=CCI*1.506
      WPI=WPI*1.122
      WRITE(IO,100) LIST
  100 FORMAT('1',///////,40A2,/)
      WRITE(IO,110) Q,DCL2,TCL2,CCL2,CNH3,RATIO
  110 FORMAT(/,T18,'Q',T26,'DCL2',T36,'TCL2',T46,'CCL2',T54,'CNH3',
     AT65,'RATIO',/,T11,6F10.3)
      WRITE(IO,130) CCI,WPI,DHR,PCT,RI,YRS,FORK1
  130 FORMAT(///,T17,'CCI',T27,'WPI',T37,'DHR',T47,'PCT',T58,'RI',T67,
     C'YRS',T75,'FORK1',/,T11,7F10.3)
      WRITE(IO,140) BVOL,CUSE,NH3USE,CAMINE
  140 FORMAT(//,T17,'BVOL',T29,'CUSE',T40,'NH3USE',T52,'CAMINE',T64,
     D/,8X,3F12.3,1X,F12.3,//)
      WRITE(IO,150)
  150 FORMAT(27X,'CON',9X,'CAP',9X,'AMM',9X,'O+M',9X,'TOT',9X,'ECF',/)
      WRITE(IO,160) CON1,CAP1,AMM1,OMC1,TOT1,ECF1
  160 FORMAT(2X,'CONTACT BASIN',5X,2F12.0,3F12.3,F12.2)
      WRITE(IO,170) CON2,CAP2,AMM2,OMC2,TOT2,ECF2
  170 FORMAT(2X,'CL2 FEED SYSTEM',3X,2F12.0,3F12.3,F12.2)
      WRITE(IO,180) CON3,CAP3,AMM3,OMC3,TOT3,ECF3
  180 FORMAT(2X,'NH3 REACTOR',6X,2F12.0,1X,3F12.3,F12.2,/)
      WRITE(IO,190) T1,T2,T3,T4,T5
  190 FORMAT(2X,'TOTAL',13X,2F12.0,3F12.3)
 1000 CONTINUE
      END
```

Figure 6A. Sample printout from chloramine cost program

10 MGD CHLORIMINE TREATMENT PLANT

Q	DCL2	TCL2	CCL2	CNH3	RATIO
7.000	3.000	20.000	300.000	200.000	5.000

CCI	WPI	DHR	PCT	RI	YRS	FORK1
2.567	1.781	5.190	0.150	0.070	20.000	1.000

AVOL	CUSE	NH3USE	CAMINE
18586.600	31.925	6.385	10854.406

	CON	CAP	AMM	O+M	TOT	ECF
CONTACT BASIN	65862.	88913.	0.328	0.000	0.328	1.43
CL2 FEED SYSTEM	60887.	82198.	0.304	0.619	0.923	1.43
NH3 REACTOR	0.	0.	0.000	0.050	0.050	1.43
TOTAL	126749.	171111.	0.632	0.669	1.301	

Figure 7A. Listing of ozone cost program

```
C     DISINFECTION BY OZONATION
      DIMENSION DMATX(20,20),CCOST(5,5),COSTO(5,5),LIST(40)
      OPEN(UNIT=1,NAME='OZONE.DAT',TYPE='OLD')
      IN=1
      IO=6
      N=1
      READ(IN,10) NCASE
   10 FORMAT(I2)
      DO 1000 I=1,NCASE
      READ(IN,15) LIST
   15 FORMAT(40A2)
      READ(IN,20) (DMATX(J,N),J=1,20)
   20 FORMAT(10F8.0,/,10F8.0)
      READ(IN,22) CCI,RPI,DHR,PCT,PI,YRS
   22 FORMAT(6F10.0)
      AF=RI*(1.+RI)**YRS/((1.+RI)**YRS-1.)
      Q=DMATX(3,N)
      DO3=DMATX(1,N)
      DTO3=DMATX(2,N)
      CKWH=DMATX(4,N)
      EO3=DMATX(5,N)
      O2CST=DMATX(6,N)
      IF(DMATX(7,N)) 25,25,26
   25 DMATX(7,N)=1.78*DMATX(3,N)**.92
   26 QP=DMATX(7,N)
      TANKC=DMATX(8,N)
      FORK=DMATX(9,N)
      PPDO3=DMATX(1,N)*DMATX(7,N)*8.33*DMATX(10,N)
      DKWHR=PPDO3*DMATX(5,N)
      IF(DMATX(9,N)) 40,40,50
   40 PPDO3=2.*PPDO3
      PPDO2=0.
      GO TO 60
   50 PPDO2=3.*PPDO3
   60 VO3=DMATX(2,N)/1440.*DMATX(7,N)*1000./7.48*DMATX(15,N)
      X=ALOG(PPDO3)
      CCOST(N,1)=EXP(-.256135+.893452*X)*1000.*CCI/2.1785
      ECOST=DKWHR*DMATX(3,N)/DMATX(7,N)*DMATX(4,N)*365.
      COSTO(N,1)=ECOST/DMATX(3,N)/3650.
      X=ALOG(VO3)
      CCOST(N,2)=EXP(2.991571+.203122*X+.109297*X**2-.004996*X**3)*
     . 1000.*CCI/2.1785
      COSTO(N,2)=0.
      CF=7.71*DMATX(1,N)*DMATX(3,N)*DMATX(14,N)
      X=ALOG(CF/1000.)
      CCOST(N,3)=EXP(4.600319+.625015*X+.031771*X**2-.003994*X**3)*
     . 1000.*CCI/2.1785
      OHRS=EXP(6.924807+.328936*X+.034333*X**2)
      XHWH=EXP(6.214495+.380521*X+.044713*X**2+.001010*X**3-
     . .000620*X**4)
      X=ALOG(DMATX(3,N))
      TMSU=EXP(7.824046+.491136*X)*PI/1.6160
      COSTO(N,3)=((OHRS+XHWRS)*DHR*(1.+PCT)+TMSU)/DMATX(3,N)/3650.
      CCOST(N,4)=DMATX(8,N)*DMATX(13,N)
      O2C=PPDO2*DMATX(3,N)/DMATX(7,N)*DMATX(6,N)*365.
      COSTO(N,4)=O2C/DMATX(3,N)/3650.
      CAP1=CCOST(N,1)*1.35
      A1=CAP1*AF/DMATX(3,N)/3650.
      T1=COSTO(N,1)+A1
      CAP2=CCOST(N,2)*1.35
      A2=CAP2*AF/DMATX(3,N)/3650.
      T2=COSTO(N,2)+A2
      CAP3=CCOST(N,3)*1.35
      A3=CAP3*AF/DMATX(3,N)/3650.
      T3=COSTO(N,3)+A3
      CAP4=CCOST(N,4)*1.35
      A4=CAP4*AF/DMATX(3,N)/3650.
      T4=COSTO(N,4)+A4
      TCON=CCOST(N,1)+CCOST(N,2)+CCOST(N,3)+CCOST(N,4)
      TCAP=CAP1+CAP2+CAP3+CAP4
      TAMM=A1+A2+A3+A4
      TOPR=COSTO(N,1)+COSTO(N,2)+COSTO(N,3)+COSTO(N,4)
      TTOT=T1+T2+T3+T4
      WRITE(IO,100) LIST
  100 FORMAT(20X,40A2,//)
      WRITE(IO,120) Q,DO3,DTO3,CKWH,EO3,O2CST,QP,TANKC,FORK
```

Figure 7A. (continued)

```
  120 FORMAT(7X,'Q',7X,'DO3',6X,'DTO3',6X,'CRHH',7X,'EO3',6X,
     . 'O2CST',8X,'QP',5X,'TANKC',6X,'FORM',/,9F10.3,//)
      WRITE(IO,125) CCI,WPI,DHR,PCT,RI,YRS
  125 FORMAT(5X,'CCI',7X,'WPI',7X,'DHR',7X,'PCI',8X,'RI',7X,'YRS',/,
     . 6F10.4,//)
      WRITE(IO,130) PPDO3,VO3,PPDO2,DXHHR,ECOSI,O2C,AF,CFM,OHRS,XHHRS,
     . TMSU
  130 FORMAT(3X,'PPDO3',7X,'VO3',5X,'PPDO2',5X,'DXHHR',5X,'ECOST',
     . 7X,'O2C',8X,'AF',7X,'CFM',6X,'OHRS',5X,'XHHRS',6X,'TMSU',
     . /,6F10.1,F10.4,4F10.1,//)
      WRITE(IO,140)
  140 FORMAT(39X,'CON',9X,'CAP',9X,'AMM',9X,'O+M',9X,'TOT',9X,'ECF',/)
      WRITE(IO,150) CCOST(N,1),CAP1,A1,COSTO(N,1),T1,DMATX(16,N)
  150 FORMAT(2X,'OZONE REGENERATING FACILITIES',1X,2F12.0,3F12.3,F12.2)
      WRITE(IO,160) CCOST(N,2),CAP2,A2,COSTO(N,2),T2,DMATX(15,N)
  160 FORMAT(2X,'AERATION BASIN,COVERS,BAFFLES',1X,2F12.0,3F12.3,F12.2)
      WRITE(IO,170) CCOST(N,3),CAP3,A3,COSTO(N,3),T3,DMATX(14,N)
  170 FORMAT(2X,'DIFFUSED AIR/OXYGEN SYSTEM',4X,2F12.0,3F12.3,F12.2)
      WRITE(IO,180) CCOST(N,4),CAP4,A4,COSTO(N,4),T4,DMATX(13,N)
  180 FORMAT(2X,'OXYGEN STORAGE TANK',11X,2F12.0,3F12.3,F12.2)
      WRITE(IO,190) TCON,TCAP,TAMM,TOPP,TTOT
  190 FORMAT(/,2X,'TOTAL',25X,2F12.0,3F12.3,///////)
 1000 CONTINUE
      END
```

Figure 8A. Sample printout from ozone (air) cost program

10 MGD OZONE TREAIMENT PLANT (AIR)

Q	DO3	DTO3	CKWH	EO3	O2CST	OP	TANKC	FORK
7.000	1.000	20.000	0.010	11.000	0.000	10.000	0.000	0.000

CCI	WPI	DHR	PCT	RI	YRS
2.5670	1.7810	5.1900	0.1500	0.0700	20.0000

PPDO3	VO3	PPDO2	DKWHR	ECOST	O2C	AF	CFM	OHRS	XMHRS	TMSU
166.6	18.6	0.0	916.3	2341.1	0.0	0.0944	54.0	521.7	224.6	7165.1

	CON	CAP	AMM	O+M	TOT	ECF
OZONE REGENERATING FACILITIES	88279.	119177.	0.440	0.092	0.532	1.00
AERATION BASIN,COVERS,BAFFLES	95330.	128695.	0.475	0.000	0.475	1.00
DIFFUSED AIR/OXYGEN SYSTEM	22420.	30266.	0.112	0.455	0.567	1.00
OXYGEN STORAGE TANK	0.	0.	0.000	0.000	0.000	1.00
TOTAL	206029.	278139.	1.028	0.546	1.574	

Figure 9A. Sample printout from ozone (oxygen) cost program

10 MGD OZONE TREATMENT PLANT (OXYGEN)

Q	DO3	DTO3	CKWH	EOJ	O2COST	GP	TANRC	FORK
7.000	1.000	20.000	0.010	11.000	0.046	10.000	37000.000	1.000

CCI	WPI	DWR	PCT	RI	YRS
2.5670	1.7810	5.1900	0.1500	0.0700	20.0000

PPDO3	VO3	PPDO2	DKWHR	ECOSI	O2C	AF	CFM	OHRS	XMHRS	TMSU
83.3	18.6	249.9	916.3	2341.1	2937.1	0.0944	54.0	521.7	224.6	7165.1

	CON	CAP	ANN	O+M	TOT	ECF
OZONE REGENERATING FACILITIES	47523.	64156.	0.237	0.092	0.329	1.00
AERATION BASIN,COVERS,BAFFLES	95330.	128695.	0.475	0.000	0.475	1.00
DIFFUSED AIR/OXYGEN SYSTEM	22420.	30266.	0.112	0.455	0.567	1.00
OXYGEN STORAGE TANK	37000.	49950.	0.185	0.115	0.299	1.00
TOTAL	202272.	273067.	1.009	0.661	1.670	

Figure 10A. Listing of granular activated carbon cost program

```
      DIMENSION LIST(40)
      OPEN(UNIT=1,NAME='CARB.DAT',TYPE='OLD')
      IN = 1
      IO = 6
      READ(IN,10) NCASE
   10 FORMAT(I2)
      DO 1000 I=1,NCASE
      PRAM1=0.
      PRAM2=0.
      PRAM3=0.
      PRAM4=0.
      CON1=0.
      CON2=0.
      CON3=0.
      CON4=0.
      CAP1=0.
      CAP2=0.
      CAP3=0.
      CAP4=0.
      AMM1=0.
      AMM2=0.
      AMM3=0.
      AMM4=0.
      OMC1=0.
      OMC2=0.
      OMC3=0.
      OMC4=0.
      TCS1=0.
      TCS2=0.
      TCS3=0.
      TCS4=0.
      TAREA=0.
      CAREA=0.
      CLENG=0.
      READ(IN,20) LIST
   20 FORMAT(40A2)
      READ(IN,30) QD,QP,PI,YRS,CCI,WPI,FORK1,FORK2
      READ(IN,30) DCARB,RHATE,HAREA,HLOAD,CDIAM,SERN,CT,CTYPE
      READ(IN,30) POWER,DHR,FUEL,CARBC,CARBM,PUMPF,CONTN,VOL1
      READ(IN,30) ECF1,ECF2,ECF3,ECF4
   30 FORMAT(8F10.0)
      CCI=CCI/1.750
      WPI=WPI/1.191
      PRAM1=QP*ECF1
      X=ALOG(PRAM1)
      CON1=EXP(3.000894+.799909*X)*1000.*CCI*PUMPF
      OMC1=0.
      IF(FORK1) 50,40,50
   40 TAREA=QD*1000000./1440./HLOAD
      CAREA=3.14159*CDIAM**2./4.
      CONTN=TAREA/CAREA
      NNN=CONTN
      CONTN=NNN+1.+2.
      CONTN=CONTN*SERN
      CLENG=HLOAD*CT/7.48
      VOL1=CAREA*CLENG/SERN
   50 TVOL=VOL1*CONTN
      PRAM2=TVOL*ECF2
      X=ALOG(VOL1*ECF2/1000.)
```

Figure 10A. (continued)

```
      CON2=EXP(4.382026+.353985*X)*CONTN*1000.*CCI
      X=ALOG(QD)
      COHRS=EXP(6.310657+.446392*X)
      CMHRS=EXP(4.492027+.841303*X)
      CLHRS=EXP(5.113394+.230261*X)
      CTHRS=COHRS+CMHRS+CLHRS
      CLAB=CTHRS*DHR
      CMATM=EXP(-1.231487+.824386*X)*1000.*WPI
      CMATP=EXP(.858226+.994503*X)*1000.*POWER/.02
      CTOT=CLAB+CMATM+CMATP
      OMC2=CTOT/QD/3650.
      IF(FORK2) 70,60,70
   60 HAREA=1.2*DCARB*QD/40.
   70 IF(HAREA-95.) 80,80,90
   80 HAREA=95.
   90 PRAM3=HAREA*ECF3
      X=ALOG(PRAM3)
      CON3=EXP(3.673707+.454840*X)*1000.*CCI
      X=ALOG(RRATE/1000.)
      ROHRS=EXP(8.676918+.440237*X)
      RMHRS=EXP(9.434925+.452111*X)
      RLHRS=EXP(5.007337+.621430*X)
      RTHRS=ROHRS+RMHRS+RLHRS
      FACTR=QD*DCARB/RRATE
      RLAB=RTHRS*DHR*FACTR
      RMATM=EXP(.606648+.389098*X)*1000.*WPI*FACTR
      RMATP=EXP(-.826456+.991087*X)*1000.*(POWER/.02)*FACTR
      RMATF=EXP(-.287682+1.000000*X)*1000.*(FUEL/.065)*FACTR
      RMATC=EXP(2.090877+.983502*X)*1000.*(CARBC/.33)*(CARBM/.08)*FACTR
      RTOT=RLAB+RMATM+RMATP+RMATF+RMATC
      OMC3=RTOT/QD/3650.
      PRAM4=TVOL*ECF4
      X=ALOG(VOL1*ECF4/1000.)
      CON4=EXP(2.302585+.987318*X)*CONTN*1000.*CCI*(CARBC/.33)
      OMC4=0.
      AF=RI*(1.+RI)**YRS/((1.+RI)**YRS-1.)
      TCON=CON1+CON2+CON3+CON4
      X=ALOG(TCON/1000000.)
      CELAI=EXP(.240573+.990929*X)*1000000.-TCON
      TCAP=TCON+CELAI
      RATIO=TCAP/TCON
      CAP1=CON1*RATIO
      CAP2=CON2*RATIO
      CAP3=CON3*RATIO
      CAP4=CON4*RATIO
      AMM1=CAP1*AF/QD/3650.
      AMM2=CAP2*AF/QD/3650.
      AMM3=CAP3*AF/QD/3650.
      AMM4=CAP4*AF/QD/3650.
      TCS1=AMM1+OMC1
      TCS2=AMM2+OMC2
      TCS3=AMM3+OMC3
      TCS4=AMM4+OMC4
      ATOT=AMM1+AMM2+AMM3+AMM4
      OTOT=OMC1+OMC2+OMC3+OMC4
      TTOT=TCS1+TCS2+TCS3+TCS4
      CCI=CCI*1.750
      WPI=WPI*1.191
      WRITE(IO,200) LIST
```

Figure 10A. (continued)

```
200 FORMAT(1H1,/////,20X,40A2,///)
    WRITE(IO,210)
210 FORMAT(53X,'COST ESTIMATE',/,58X,'FOR',/,42X,
   . 'GRANULAR ACTIVATED CARBON TREATMENT',
   . ///,6X,'PROCESS COMPONENTS',12X,'DESIGN',6X,'CONSTRUCTION',
   . 5X,'CAPITAL',3X,'DEBT COST',4X,'O+M COST',2X,'TOTAL COST',5X,
   . 'EXCESS',/,35X,'PARAMETER',4X,'COST, $',10X,'COST, $',3X,
   . 'CTS/1000',5X,'CTS/1000',3X,'CTS/1000',5X,'CAPACITY',//)
    WRITE(IO,220) PRAM1,CON1,CAP1,AMM1,OMC1,ICS1,ECF1
220 FORMAT(1X,'INFLUENT PUMP STATION',8X,F12.2,1X,'MGD',2X,
   . 2F12.0,3F12.3,F12.2)
    WRITE(IO,230) PRAM2,CON2,CAP2,AMM2,OMC2,ICS2,ECF2
230 FORMAT(1X,'CARBON CONTACTORS',12X,F12.0,1X,'CU FT',
   . 2F12.0,3F12.3,F12.2)
    WRITE(IO,240) PRAM3,CON3,CAP3,AMM3,OMC3,ICS3,ECF3
240 FORMAT(1X,'CARBON REGENERATION SYSTEM',3X,F12.0,1X,'SQ FT',
   . 2F12.0,3F12.3,F12.2)
    WRITE(IO,250) PRAM4,CON4,CAP4,AMM4,OMC4,ICS4,ECF4
250 FORMAT(1X,'INITIAL CARBON CHARGE',8X,F12.0,1X,'CU FT',
   . 2F12.0,3F12.3,F12.2)
    WRITE(IO,260)
260 FORMAT(50X,'----------',2X,'----------',2X,'----------',2X,
   . '----------',2X,'----------')
    WRITE(IO,270) TCON,TCAP,ATOT,OTOT,TTOT
270 FORMAT(1X,'SUBTOTAL',39X,2F12.0,3F12.3)
    WRITE(IO,280) CELAI
280 FORMAT(1X,'ENG.,LAND,ADMIN.,INT., COSTS',19X,F12.0)
    WRITE(IO,290)
290 FORMAT(50X,'----------')
    WRITE(IO,300) TCAP
300 FORMAT(1X,'GRAND TOTAL',36X,F12.0)
    WRITE(IO,290)
    WRITE(IO,290)
    WRITE(IO,310)
310 FORMAT(/////)
    WRITE(IO,320) QD,QP,RI,YRS,CCI,WPI,FORK1,FORK2
    WRITE(IO,330) DCARB,RRATE,HAREA,HLOAD,CDIAM,SERN,CT,CTYPE
    WRITE(IO,340) POWER,DHR,FUEL,CARBC,CARBM,PUMPF,CONTN,VOL1
320 FORMAT(6X,'QD',8X,'QP',8X,'RI',7X,'YRS',7X,'CCI',7X,'WPI',
   . 5X,'FORK1',5X,'FORK2',/,8F10.3,/)
330 FORMAT(3X,'DCARB',5X,'RRATE',5X,'HAREA',5X,'HLOAD',5X,'CDIAM',
   . 6X,'SERN',8X,'CT',5X,'CTYPE',/,8F10.3,/)
340 FORMAT(3X,'POWER',7X,'DHR',6X,'FUEL',5X,'CARBC',5X,'CARBM',
   . 5X,'PUMPF',5X,'CONTN',6X,'VOL1',/,8F10.3,///)
    WRITE(IO,350) COHRS,CMHRS,CLHRS,CTHRS,CLAB,CMATM,CMATP,CTOT
350 FORMAT(1X,'CONTACTOR O+M    =',4X,'COHRS',5X,'CMHRS',5X,'CLHRS',
   . 5X,'CTHRS',6X,'CLAB',5X,'CMATM',5X,'CMATP',6X,'CTOT',/,
   . 20X,8F10.0,/)
    WRITE(IO,360) ROHRS,RMHRS,RLHRS,RTHRS,RLAB,RMATM,RMATP,RMATF,
   . RMATC,RTOT
360 FORMAT(1X,'REGENERATION O+M =',4X,'ROHRS',5X,'RMHRS',5X,'RLHRS',
   . 5X,'RTHRS',6X,'RLAB',5X,'RMATM',5X,'RMATP',5X,'RMATF',5X,
   . 'RMATC',6X,'RTOT',/,20X,10F10.0)
    WRITE(IO,370) CONTN,TAREA,CAREA,CLENG,TVOL,VOL1
370 FORMAT(///,3X,'CONTN',5X,'TAREA',5X,'CAREA',5X,'CLENG',6X,
   . 'TVOL',6X,'VOL1',/,6F10.2)
1000 CONTINUE
    END
```

Figure 11A. Sample printout from granular activated carbon program

10 MGD GRANULAR ACTIVATED CARBON TREATMENT PLANT

COST ESTIMATE
FOR
GRANULAR ACTIVATED CARBON TREATMENT

PROCESS COMPONENTS	DESIGN PARAMETER	CONSTRUCTION COST, $	CAPITAL COST, $	DEBT COST CTS/1000	O+M COST CTS/1000	TOTAL COST CTS/1000	EXCESS CAPACITY
INFLUENT PUMP STATION	10.00 MGD	0.	0.	0.000	0.000	0.000	1.00
CARBON CONTACTORS	8650. CU FT	1114762.	1409839.	5.209	0.817	6.026	1.00
CARBON REGENERATION SYSTEM	185. SQ FT	621497.	786007.	2.904	8.237	11.140	1.00
INITIAL CARBON CHARGE	8650. CU FT	146377.	185123.	0.684	0.000	0.684	1.00
SUBTOTAL		1882637.	2380969.	8.796	9.054	17.850	
ENG.,LAND,ADMIN.,INT., COSTS		498332.					
GRAND TOTAL		2380969.					

QD	QP	RI	YRS	CCI	WPI	FORK1	FORK2
7.000	10.000	0.070	20.000	2.567	1.781	1.000	0.000
DCARB	**RRATE**	**HAREA**	**HLOAD**	**CDIAM**	**SERN**	**CT**	**CTYPE**
882.650	6178.570	185.357	0.000	0.000	0.000	4.500	0.000
POWER	**DHR**	**FUEL**	**CARBC**	**CARBM**	**PUMPF**	**CONTN**	**VOL1**
0.010	5.190	0.126	0.380	0.100	0.000	10.000	865.000

CONTACTOR O+M =	COHRS	CMHRS	CLHRS	CTHRS	CLAB	CMATM	CMATP	CTOT		
	1312.	459.	260.	2031.	10542.	2171.	8169.	20881.		
REGENERATION O+M =	ROHRS	RMHRS	RLHRS	RTHRS	RLAB	RMATM	RMATP	RMATF	RMATC	RTOT
	13077.	10491.	464.	24032.	124724.	5571.	1330.	8983.	69835.	210443.

CONTN	TAREA	CAREA	CLENG	TVOL	VOL1
10.00	0.00	0.00	0.00	8650.00	865.00